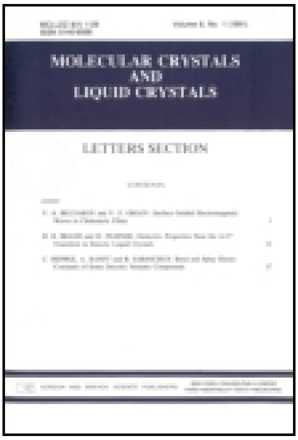

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Characteristics of a-SiGe:H Solar Cell with various Thickness Ratio of a-Si:H/a-SiGe:H Layer in the Intrinsic Layer

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In the present work, we have investigated the characteristics of a-SiGe:H solar cell with an optical absorption layer (a-Si:H, a-SiGe:H) between p-layer and n-layer. The characteristics of the fabricated a-SiGe:H solar cells were carried out with a-Si:H and a-SiGe:H according to various thickness in the intrinsic layer. The entire thickness of a-Si:H and a-SiGe:H layers were 2000 Å whereas thickness of a-Si:H layer was varied from 50 Å to 800 Å. Modulating thickness of a-Si:H layer, we verified parameter characteristics of fabricated solar cell such as open-circuit voltage (V_{OC}), short-circuit density current (J_{SC}), fill factor (FF), and conversion efficiency (η) comparing with a-SiGe:H solar cell by using an XEC-301S solar simulator that was composed of a Xenon lamp and AM filter under standard AM 1.5G conditions. Further analysis the UV-VIS Spectrometer and Quantum efficiency (QE) are used to verify the transmittance and absorptance, respectively. It was observed that the higher performances (V_{oc}: 0.54 V, J_{sc}: 20.64 mA/cm^2, FF: 0.41 and η: 4.59%) of a-SiGe:H solar cell with thickness of a-Si:H layer in the intrinsic layer. This ascribed to fact that the insertion of a-Si:H layer increased the performance by influencing the intrinsic layer of a-Si:H solar cell.

Keywords a-Si:H; a-SiGe:H; solar cells; conversion efficiency; PECVD

Introduction

Over the past decade, rapid development have taken place in hydrogenated amorphous silicon (a-Si:H) p-n junction and in device application, due to the attractive feature of a-Si:H and related materials. These amorphous based devices have intensively researched for high absorption coefficient in the visible range of the solar spectrum and are able to fabricate the low-cost and low temperature as using the plasma enhanced chemical vapor deposition (PECVD). The unique combination of bandgap absorber, quality, and crystallization in the a-Si:H are able to make high efficiency of solar cell and to apply for several device[1–3]. However, the solar cell based the a-Si:H still needs to have the high efficiency and it is significantly important for commercialization.

The solar cell based a-Si:H consists of three active layers in a p-i-n structure. The p-doped and n-doped layers cause an electrical field across the intrinsic absorber layer,

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which is sandwiched between the doped layers. Absorbed light in this layer results in the generation of electrons and holes, which is separated by the electric field. The electrons and holes are collected at the opposite contacts of the solar cell. In recent years, a-Si:H and alloys based solar cells have been researched in order to increase the efficiency of solar cells. Among these alloy materials, the a-SiGe:H alloys has been explored extensively for photovoltaic application as the narrow bandgap absorber than that of the a-Si:H, which allows an increase of the utilization of the solar spectrum at a long wavelength and the stabilized efficiency of solar cells [4–9]. In addition, the alloys are able to modify the deposition condition by the using the PECVD.

In this work, we investigated the characteristics of a-SiGe:H thin film solar cells with a-Si:H and a-SiGe:H according to various thickness in the intrinsic layer by PECVD method. The open-circuit voltage (V_{OC}), short-circuit density current (J_{SC}), fill factor (FF), and conversion efficiency (η) are estimated at different thickness. The varied cell performances were demonstrated through UV-VIS Spectrometer analysis and the surface roughness of a-SiGe:H layer various thickness with a-Si:H and a-SiGe:H.

Experimental details

The a-Si:H and a-SiGe:H layers were prepared using a oneside coated ITO(indium tin oxide) glass with a sheet resistance of 7∼8 Ω/□. The thickness of a-Si:H and a-SiGe:H films for an intrinsic layer is 2000 Å, and deposited using He based 10% SiH_4 diluted and H_2 based 10% GeH_4 diluted. Doping gases in a-Si:H layer for p- and n-layer with a thickness level of 300, 600 Å, respectively, were diluted H_2 3% B_2H_6 and 1% PH_3, respectively. The working pressure and substrate temperature were 750 mTorr and 250°C during deposition, respectively. All films were deposited by a 13.56 MHz PECVD.

Figure 1 shows the fabricated p-i-n solar cell structure. The thicknesses of the p-layer and n-layer were fixed to 300 Å and 600 Å respectively. Table 1 shows the deposition conditions of the layers, also the cell performances with thickness of a-SiGe:H are shown

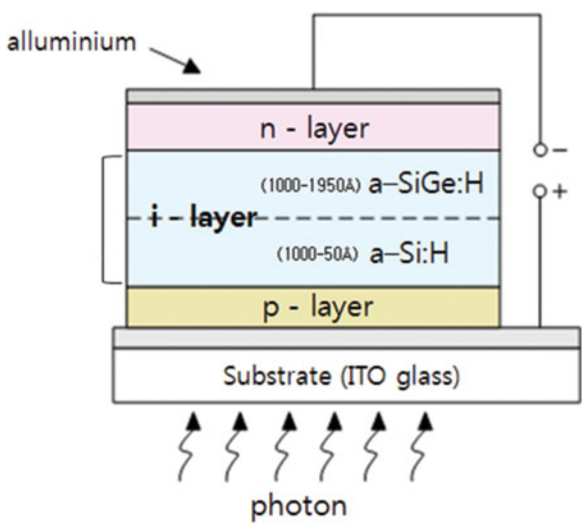

Figure 1. The structure of the p-i-n solar cell.

Table 1. Deposition Conditions of p-layer and n-layer

	p-a-Si:H	n-a-Si:H
Gas	SiH_4 / B_2H_6	SiH_4 / PH_3
Gas Flow rate (sccm)	100/30	100/20
RF power (W)	100	100
Substrate temperature (°C)	250	250
Reaction pressure (mTorr)	750	750
Thickness (nm)	30	60

in Table 2. The a-Si:H and a-SiGe:H for the intrinsic layer were deposited using ($SiH_4 + H_2$) and ($SiH_4 + H_2 + GeH_4$) gas mixture, respectively.

We compared characteristics of solar cell having 200 Å a-Si:H and 1800 Å a-SiGe:H with one deposited only a-SiGe:H for i-layer, we verified improved V_{oc} and efficiency at the former cell. The film's thickness was measured by α-Step analysis. The optical properties of the films were measured by UV-VIS Spectrometer analysis. The various values of V_{oc}, J_{sc}, FF, and conversion efficiency were measured using the solar simulator. The J-V characteristic and the QE (quantum efficiency) of these cells have been measured. The root-mean-square roughness (RMS) of intrinsic layer with a-Si:H layer thickness were measured by Atomic Force Microscopy (AFM).

Results and Discussion

Figure 2 shows illuminated J-V characteristics curves of a-SiGe:H solar cells according to the various thickness ratios of the a:Si:H/a:SiGe:H layer in the intrinsic layer. When the thickness of a-Si:H in the intrinsic layer was decreased from 1000 to 200 Å, the J_{SC} characteristics of a-SiGe:H solar cells increased from 6.86 to 20.64, whereas, the J_{SC} characteristics of a-SiGe:H solar cells sharply decreased as more decrease the thickness of a-Si:H in the intrinsic layer. Figure 3 shows the V_{OC}, J_{SC}, FF and η of the a-SiGe:H thin film solar cells according to the various thickness ratios of the a:Si:H/a:SiGe:H layer in the intrinsic layer. The solar cell is generally estimated by the characteristics of the energy-conversion efficiency (η) and it is very important parameter in the solar cell. The η is sufficiently calculated by the measured V_{oc}, J_{sc}, and FF [8]. The parameter characteristics of a-SiGe:H

Table 2. Cell performances with thickness of a-SiGe:H

	V_{oc} (V)	J_{sc} (mA/cm^2)	FF	η (%)
a – SiGe:H (1200 Å)	0.32	6.86	0.30	0.95
a – SiGe:H (1400 Å)	0.51	10.68	0.31	1.75
a – SiGe:H (1600 Å)	0.54	15.02	0.33	2.72
a – SiGe:H (1800 Å)	0.53	20.64	0.41	4.59
a – SiGe:H (1850 Å)	0.45	19.92	0.38	3.52
a – SiGe:H (1900 Å)	0.37	17.17	0.30	2.00
a – SiGe:H (1950 Å)	0.37	11.69	0.29	1.26
a – SiGe:H (2000 Å)	0.41	18.96	0.48	3.79

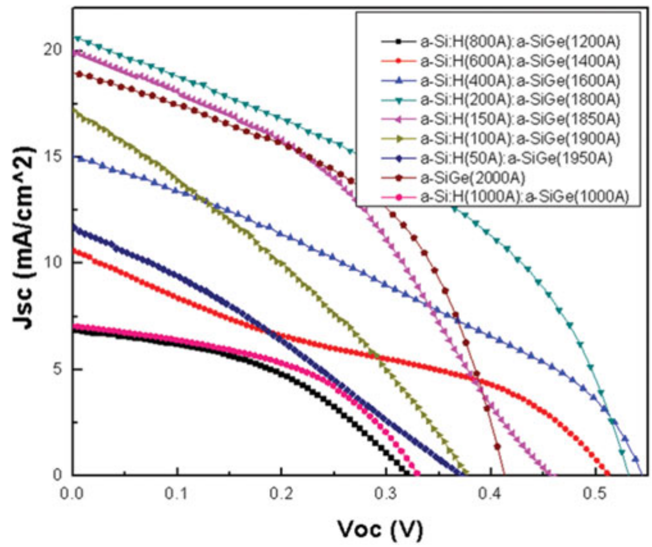

Figure 2. J-V characteristics curves of a-SiGe:H solar cells according to the various thickness ratios of the a:Si:H/a:SiGe:H layer in the intrinsic layer.

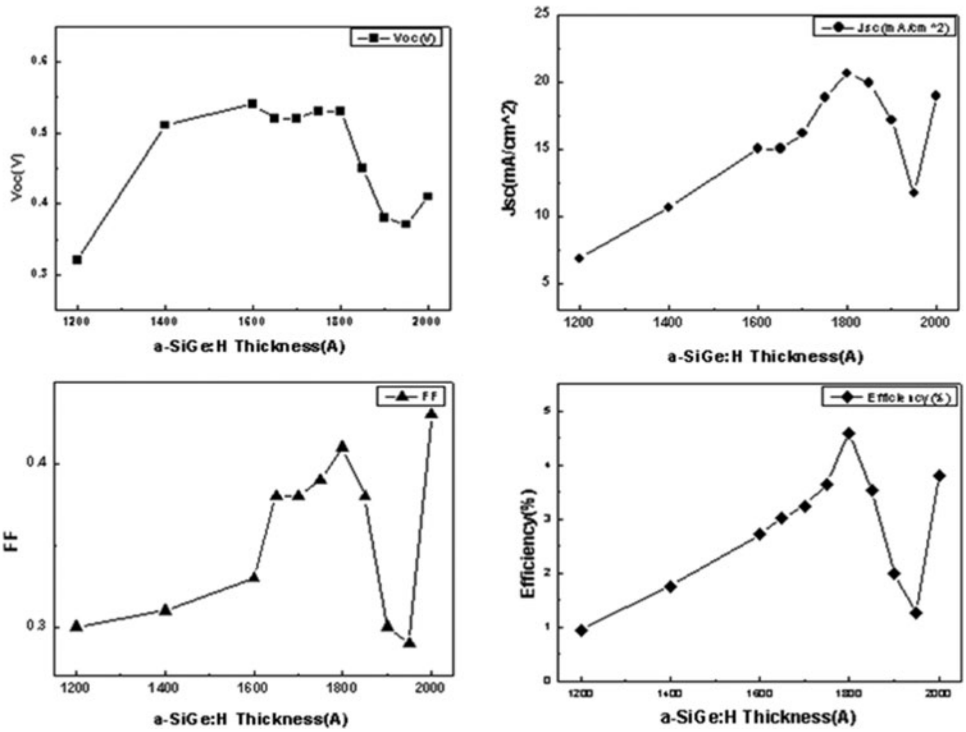

Figure 3. The V_{OC}, J_{SC}, FF and η of the a-SiGe:H thin film solar cells according to the various thickness ratios of the a:Si:H/a:SiGe:H layer in the intrinsic layer.

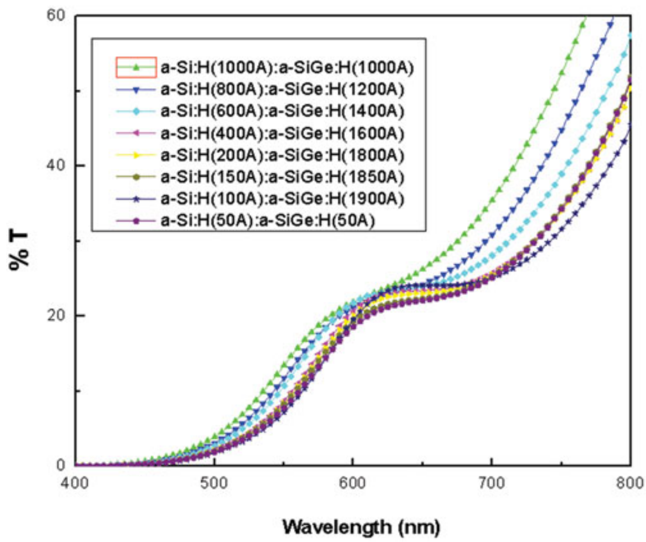

Figure 4. The transmittance spectra according to varying thickness of a-Si:H and a-SiGe:H in the intrinsic layer.

solar cells modulating intrinsic layer summarized in Table. 2. The best performance of open-circuit voltage (V_{OC}), short-circuit density current (J_{SC}), fill factor (FF), and conversion efficiency (η) are of 0.53 V, 20.64 mA/cm^2, 0.41, and 4.59%, respectively for the solar cell having a thickness layer of a-Si:H (200 Å) and a-SiGe:H (1800 Å) in the intrinsic layer. From these results, we confirmed that the characteristics of a-SiGe:H solar cells should be improved by adding a-Si:H in the intrinsic layer and the optimal conditions of a-Si:H and a-SiGe:H thickness were 200 Å and 1800 Å respectively. Moreover, anticipated the cause of improved results because the interface between p and i layer was changed by insulting a-Si:H layer. As observed from Figure 4, the transmittance spectra according to varying thickness of a-Si:H and a-SiGe:H in the intrinsic layer. Light transmittance is decreased by increasing the thickness of a-SiGe:H. This indicates that the band gap of a-SiGe:H is smaller than a-Si:H and absorption has been made from a longer wavelength than a-Si:H. Furthermore, confirmed that the absorption region of the thickness of with a-Si:H (200 Å) and a-SiGe:H (1800 Å) was smaller changed than the thickness of a-Si:H (1000 Å) and a-SiGe:H (1000 Å). Figure 5 shows the quantum efficiency of the a-SiGe:H solar cells with the thickness of a-Si:H in the intrinsic layer. We verified that a solar cell with a 1800 Å thickness of a-SiGe:H layer absorbs the most photon energy throughout the whole wavelength. For a wavelength bandgap decreased whereas the absorption increases. The external quantum efficiency (EQE) is defined as the ratio of collected charge carriers versus incoming photons at each wavelength [9]. In order to verify the p/i interface caused the changed characteristics of a-SiGe:H solar cells with the thickness of a-Si:H in the intrinsic layer, the surface roughness of the a-Si:H in a-SiGe:H layer with respect to the thickness of a-Si:H were measured by AFM. Figure 6 shows the measured results. The RMS of the surface roughness was decreased from 0.190 to 0.040 nm as the thickness of a-Si:H increased from 0 to 250 Å. The efficiency of a-SiGe:H solar cell is highest when thickness of a-Si:H is 200 Å. This means that the characteristics of a-SiGe:H solar cell in a p-i-n structure is improved because the compensating defects of interface within p- and i-layer

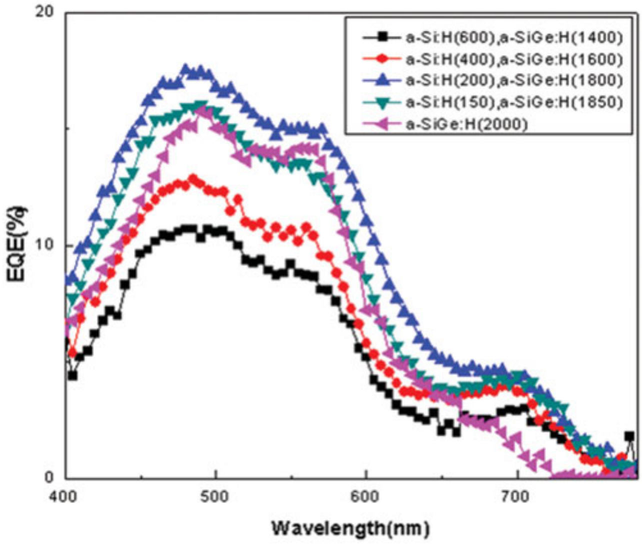

Figure 5. The quantum efficiency of the a-SiGe:H solar cells with the thickness of a-Si:H in the intrinsic layer.

was decreased by inserting the a-Si:H layer in the intrinsic layer [10]. When thickness layer of a-Si:H is 200 Å, the compensating defects of p/i interface in a-SiGe:H solar cells were more decreased than the order thickness of a-Si:H layer. Moreover, we observed that the thickness of a-Si:H in the intrinsic layer is over 250 Å, the bandgap absorber is decreased due to variation of a-SiGe:H alloy.

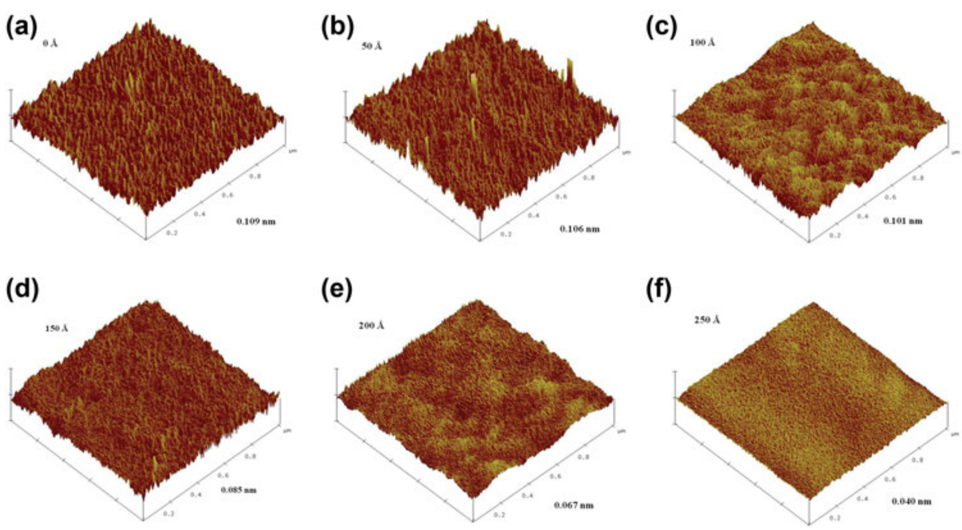

Figure 6. The surface roughness of the a-Si:H in a-SiGe:H layer with respect to the thickness of a-Si:H.

Conclusion

In this study, we have investigated the optical properties and the J-V characteristics of the a-SiGe:H solar cells deposited using the PECVD method. The influence of a-Si:H and a-SiGe:H intrinsic layer on the electrical characteristics of a-SiGe:H solar cells have been carried out in the various thickness range of (1000–2000 Å) a-SiGe:H and (1000–50 Å) a-Si:H. However, it is evaluated the characteristics of solar cells by different thickness of a-Si:H and a-SiGe:H which have a different band gap in optical absorption layer with total thickness 2000 Å. From the above results, confirmed that when it comes to 1800 Å thickness of a-SiGe:H layer, 200 Å thickness of a-Si:H layer, respectively, they allow for the best attributes in on the solar cell. Furthermore, verified that the cell efficiency having the a-SiGe:H 2000 Å (3.7%) and when thickness of a-Si:H and a-SiGe:H is 200 Å and 1800 Å, efficiency of a-SiGe:H solar cell is 4.59%. These results indicates that the absorption region and roughness were changed with various thickness ratios of the a:Si:H/a:SiGe:H layer in the intrinsic layer. Finally, we have concluded that the compensating defects of interface within p- and i-layer, a-SiGe:H solar cell efficiency is improved by inserting a-Si:H layer in the intrinsic layer.

Acknowledgments

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